

D-20792



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AMENDMENTS TO THE DRAWING

A replacement drawing has been submitted herewith in which outer oxygen passage 12 is indicated.

**REMARKS**

Claim 1 has been amended in order to more clearly point out the subject matter that Applicants' regard as their invention. As such, claims 1-10 are presently pending.

The Examiner rejected claims 1, 3, 4, 7, 9 and 10 under 35 U.S.C. §103(a) as being unpatentable over Burch et al. (U.S. 2004/0154222) ("Burch") in view of Abe et al. (U.S. 6,576,203) ("Abe"). Applicants submit that even if the references were combined in the manner suggested by the Examiner, the resulting combination would not render Applicants' invention obvious because among other features of the invention as claimed, such rejection would not disclose a mixing chamber having an orifice to expand a heated oxygen containing stream into the mixing chamber nor at least two endothermic reforming reaction zones containing a precious metal catalyst supported on supports formed of different materials that provide a greater surface area for a successive endothermic reforming reaction zones than an initial endothermic reforming reaction zone. As will be discussed, is this latter feature that provides a much greater surface area than is possible in the Burch reference and therefore, a design of an autothermal reformer that is capable of greater throughput or of more compact design than the prior art.

Applicants' invention as recited in amended claim 1 specifically calls for an autothermal reactor having a mixing chamber that is provided with an orifice to expand a heated oxygen containing stream into the mixing chamber. An inlet is located adjacent to the orifice and oriented to introduce a hydrocarbon containing stream into the mixing chamber tangentially to the heated oxygen containing stream such that the hydrocarbon containing stream is entrained in the heated oxygen containing stream to mix the heated oxygen with the hydrocarbons at a sufficiently rapid rate so as not to react the oxygen and the hydrocarbons. Additionally, also disclosed in claim 1 is an initial partial oxidation reaction zone having a supported partial oxidation catalyst that is in communication

with the mixing chamber. This is followed by at least two endothermic reforming reaction zones heated by the exothermic reaction of the partial oxidation reaction zone. Importantly the at least two endothermic reforming reaction zones contain a precious metal catalyst that are supported on supports formed of different materials that provide a greater surface area for endothermic reforming reaction zones that are successive to or in other words, located downstream, from an initial of the endothermic reforming reaction zones. The successive of the endothermic reforming reaction zones are configured to operate at an ever decreasing operational temperature such that a material making up the support of the at least successive endothermic reforming reaction zones remains stable.

With respect to the injection of oxygen and a hydrocarbon stream, the Burch reference has an arrangement that is the complete reverse that called for in amended claim 1. Burch discloses an autothermal reactor 70 which comprises a mixing chamber 80. A liquid fuel injector 72 sprays a liquid hydrocarbon fuel into the mixing region 80. An air/steam mixture from a pipe 74 is received by a flow distribution device 76 that distributes it into mixing region 80 where it mixes with the sprayed fuel. See Paragraph 26. As such, it would appear in Burch that the oxygen containing mixture is entrained into the fuel. In any event what is not disclosed is the recitation of amended claim 1 in which a heated oxygen containing stream is expanded into the mixing chamber through an orifice and an inlet located adjacent to the orifice, oriented to introduce a hydrocarbon containing stream into the mixing chamber tangentially to the heated oxygen containing stream such that the hydrocarbon containing stream is entrained in the heated oxygen containing stream. This allows, as also recited in amended claim 1, is for the mixing to be accomplished at a sufficiently rapid rate so as not to react the oxygen with the hydrocarbons and thereby produce an unreacted mixture. In contrast to this in Burch, the mixture formed in its device is a combustible mixture and to minimize

the auto ignition risk, a thin uncatalyzed substrate 86 is positioned before the electrically heated catalyst region 84.

As the Examiner correctly points out, Burch has an initial partial oxidation reaction zone 84 and at least two endothermic reaction zones 90 and 92 containing a precious metal catalyst mounted on a suitable substrate or monolith 90. The Examiner goes on to state that Burch is silent as to the supports being formed of materials that provide a greater surface area for successive reaction zones and to fill this gap in the disclosure, Abe is cited. Applicants submit, however, the Examiner's description of Abe is also not correct. In Abe, Fig. 1, a reactor is disclosed that does comprise an initial reaction zone and a successive reaction zone. However, the Examiner's incorrect where he states that "the support of zone 1 is formed of a material providing a greater surface area than the support of zone 2."

Applicants submit that the Fig. 1 embodiment cited by the Examiner is not an embodiment of Abe that is at all close to Applicants' invention. In the paragraph that bridges cols. 5 and 6 of Abe, it is stated, that where the catalyst unit is a honeycomb structure, it is preferable that the two catalyst units satisfy relationship 3 in that reaction taking place within the catalyst unit is not as fast as combustion. This would be the case for instance in an endothermic steam reforming reaction. In relationship 3, the cell density of the upstream catalyst unit is greater than or equal to the cell density of the downstream catalyst unit. In a honeycomb structure there would be more passages to increase the surface or as set forth in the examples, the length of the units can be manipulated. However, to increase the cell density what is required is that there would be more cells for more passages within the honeycomb unit. Consequently, contrary to the Examiner's position on Fig. 1, the upstream catalyst unit would have more cells or a greater surface area than the downstream unit. As explained in col. 6, lines-6-13, Abe, where a reaction takes place in the catalyst unit that is not combustion it is preferable to increase the cell

density into the upstream catalyst to increase the contact efficiency between the reactant and the catalyst sites in order to accelerate the reaction after the temperature reaches an operational temperature of the unit. The purpose of this is that where the reactant stream contains a poisonous material, the increased cell density will compensate for the decreased number of active sites that result from poisoning. The Examiner is correct where he states that the upstream catalyst can have less of a heat capacity and therefore operate at a higher temperature than the downstream catalyst.

In Abe, more apropos to the discussion is the second embodiment, a discussion of which begins on col. 6, line 31. In such embodiment, the reaction in the catalytic unit is essentially exothermic or endothermic. Specifically, in col. 6, starting on line 45, what is described is a situation in which the reaction is accompanied by the absorption of a large quantity of heat, namely an endothermic reaction of the type that would exist in a stream methane reforming unit. Practically, the stream flowing into the downstream catalytic unit contains a lower concentration of reactant because it has already been treated by the upstream side catalyst unit and thus it is preferable to increase the cell density of the downstream side catalyst unit to increase the contact efficiency.

Applicants respectfully submit though that the point that the Examiner is missing in the description of Abe is that an increase in cell density is not the same as utilizing reaction zones that are made of different materials. In the present invention as indicated in paragraph 16 and as recited in claim 8, the initial endothermic reforming reaction zones have a surface area from about .1 to about $10\text{m}^2/\text{gram}$ and the successive reforming zone can have a surface area from between about 5 to about $30010\text{m}^2/\text{gram}$. Thus, the difference in surface area provided by the materials provides specific surface area on a weight basis between reaction zones that can vary from 50 to 3000 times. However, in the Abe reference, as indicated in col. 6, lines 19-26 there is only so much surface

area modification that can be made in that the pressure drop becomes excessive as the cell density is increased. In Abe, there is nothing that discloses the material making up the supports could be different in that metal monoliths are used that are coated with a slurry containing gamma alumina and the catalyst. As such, while the surface area of a downstream catalytic unit of Abe can be greater this is not due to the use of different materials, rather, it is due to the use of supports having a different configuration that are of the same material.

Lastly, the use of two separate materials also allows upstream reformer stage to operate at a much higher temperature than the downstream reforming zone in that alpha alumina can be used as the upstream stage and relative temperature sensitive gamma alumina having a high surface area can be used for the downstream stage. As a result, a reformer of the present invention is capable of handling a far greater throughput or can be made more compact. Thus, not also disclosed in the Examiner's rejecting combination is that the operational temperatures of the materials making up the support are selected such that the downstream, high surface area reaction stage remains stable. This feature also included in amended claim 1 and is not disclosed in the Abe reference.

Since claim 1 is in allowable form, Applicants submit that claims 2-10 should be in allowable form. However, Applicants believe that certain comments are in order. With respect to claim 2, it is stated that the mixing chamber is defined by an inner surface that outwardly diverges from the orifice to form a frustum of a cone in that it outwardly diverges at an angle that is calculated to inhibit recirculation. However, in Abe this is the exact reverse in that the mixing chamber does not outwardly diverge, it inwardly converges. Claim 6 has been indicated by the Examiner as having allowable subject matter. As to claim 8, the surface area of the initial and subsequent reforming zones are not disclosed in the Examiner's rejecting combination.

The Examiner rejected claim 2 under 35 U.S.C. §103(a) as being unpatentable over Burch in view of Abe as applied to claim 1 and further in view of Sederquist. Applicants submit that this ground of rejection is hereby rendered moot.

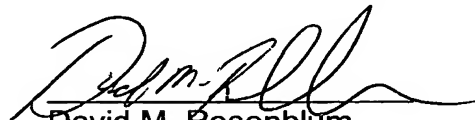
The Examiner rejected claims 5 and 8 under 35 U.S.C. §103(a) as being unpatentable over Burch in view of Abe as applied to claims 1 and 3 above and further in view of Sonetaka et al. (U.S. 4,211,672). ("Sonetaka") Given the allowability of claim 1 over the Burch and Abe references this rejection is likewise rendered moot. However, several comments are in order given the above discussion. The Examiner here admits that the collective teachings of Burch and Abe are silent as to the specifically claimed configuration of selecting alpha aluminum as a support material in the initial reaction zone and gamma alumina in the support material in the successive reaction zone. This is not correct in that Abe is quite clear that the same material used in both reaction zones, at least in the examples. The Burch and Abe references are also silent about the specific claimed configuration of the specific surface areas as also admitted by the Examiner. Applicants submit that Abe is silent about these configurations because the Abe reference, in particular, is incapable of producing such specific surface areas as claimed between the two successive zones of Abe, different support materials are not contemplated. The Examiner says that it would be obvious for one of ordinary skill in the art to select the claimed configuration for reaction zones on the basis of suitability for intended use and absent showing unexpected results. However, in this case, the use of two different materials having different specific surface areas by their very nature are unexpected to allow for a configuration to be produced having the advantageous outlined above. Conventional alpha alumina carriers have the surface areas described in Sonetaka. This reference adds nothing that would render Applicants' invention obvious given the fact that there is no teaching to utilize the different materials in two excessively placed

reaction zones to provide a greater specific surface area in a second reaction zone than the first reaction zone.

Applicants are aware that this response is being made within the first month. Consequently, a petition to extend the time to answer in the first month is attached hereto together with directions to charge deposit account no. 16-2440 and the appropriate fee to extend the time to answer within the first month.

In view of the amendments to the claims and drawing and the remarks set forth above, Applicants request reconsideration of the rejection and allowance of all presently pending claims. Since the claims are in condition for allowance, prompt and favorable action is solicited.

Respectfully submitted,



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October 25, 2006

Attachment: Replacement drawing